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RESEARCH AND DEVELOPMENT
REPORT 165
MARCH 1962

RESULTS OF A FIELD STUDY OF THE TIDE LINE MECHANISM

Subproject No. SF 011 01 01 · Task No. 2612

G. B. AUSTIN
R. H. PAYNE

UNITED STATES NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

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ABSTRACT

The concentration of foam and trash to form a visible line along the boundary between two dissimilar water masses is a daily occurrence in the waters near Panama City, Florida. The name "tide line" is used to designate this phenomenon as its development and degeneration coincide with the ebb and flow of the tide. During the falling tide the water from St. Andrew Bay flows through the jetties into the Gulf of Mexico spreading outward as a thin surface layer. A brief investigation of this estuarine sea water boundary, carried out under various weather and sea conditions, was undertaken in the early winter of 1959. The thin layer of overlying estuarine water was found to be two to four feet deep with its front, the tide line, generally extending more than three miles offshore, before the rising tide caused its breakup. Abrupt changes in sound velocity, temperature, and salinity occurred at the interface between the estuarine and Gulf water masses. Based on the preliminary results obtained, a recommendation to continue investigation of "tide line" phenomenon is made.

ADMINISTRATIVE INFORMATION

Research subproject CX-5 FUST (SF 011 01 01) Task 2612 was established by Bureau of Ships letter A11/NS 870 100(631) ser 631-739 of 21 July 1958 for the purpose of conducting fundamental studies to improve Mine and Torpedo Countermeasures and to better utilize the available data in preparing instructions for the forces afloat. The work on FUST Subtask 15 (TIDE LINE) began October 1959. The completion date of the work conducted under this task was January 1960.

This report covers results of the work performed during the period cited above and represents essentially the material used in a technical paper presented to the 41st Annual Meeting of the American Geophysical Union in April 1960.

APPROVED AND RELEASED 26 FEBRUARY 1962

N. H. Jasper, Dr. Eng.
Technical Director

W. C. Bennett, Jr., CAPT, USN
Commanding Officer and Director

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GLOSSARY AND SYMBOLS

1. Front - the boundary surface of intersection between two water-masses, one of which may be flowing or moving relative to the other.

2. db - decibel, as used in underwater sound transmission refers sound intensity I_1, to a reference pressure level of 1 dyne/cm^2 under the assumption of plane waves as follows:

$$I_1(\mathrm{db}) = 10 \log \frac{p^2/\rho_o c_o}{po^2/\rho_o c_o} = 20 \log \frac{p}{p_o} = 20 \log p_1 \quad .$$

Where p_1 is the incident excess pressure in units of dyne/cm^2.

3. Dy - a symbol denoting the diameter of a jet orifice for axial jet flow and/or the slot-width of a jet orifice for plane jet flow.

4. homopycnal - an inflow of river or estuarine water having the same or like density as sea water into which it flows.

5. hyperpycnal - an inflow of river or estuarine water having a greater density than sea water under which it flows.

6. hypopycnal - an inflow of river or estuarine water having a lesser density than sea water over which it flows.

7. Isohaline - an imaginary line connecting points of equal salinity in the ocean.

8. Jetties - refers to the man-made passage which connects St. Andrew Bay to the Gulf of Mexico (Figure 3).

9. Salinity (o/oo) - the total amount of solid material in grams contained in one kilogram of sea water when all of the carbonate has been converted to oxide, the bromine and iodine replaced by a chlorine equivalence and all organic matter completely oxidized. The symbol, o/oo, denotes parts per thousand and/or grams per kilogram.

GLOSSARY AND SYMBOLS (CONT'D)

10. Sigma t - $\sigma_t = \sigma_{s,t,o} \div 1000\ (\rho_{s,t,o} - 1)$, an anomaly of sea water density at standard atmospheric pressure.

11. Tide line - the boundary line of intersection of an oceanic front at the sea surface; the movement and geometry of which is regulated in large part by tidal forces.

12. $\underline{U}$ - a symbol denoting a velocity vector in the X direction of the Cartesian coordinate frame of reference.

13. $\underline{U_o}$ - a symbol denoting the steady-state core velocity vector at the orifice of a plane jet inflow.

14. $\underline{V_B}$ - a symbol denoting a water velocity vector in the bottom or lower reaches of a water column.

15. $\underline{V_m}$ - a symbol denoting a water velocity vector in the middle reaches of a water column.

16. $\underline{V_u}$ - a symbol denoting a water velocity vector in the upper reaches of a water column.

17. Velocity gradient - the change (increase or decrease) of the magnitude of a fluid velocity with respect to distance in a direction normal to the direction of fluid flow.

18. Velocity shear zone - A region of relative velocity difference within a fluid medium characterized by two contiguous layers of the medium "sliding" with respect to each other in a direction tangent to the common surface of contact.

19. $\underline{\frac{X}{Dy}}$ - denotes the ratio of centerline distance downstream from a plane jet orifice to the width of the orifice.

20. $\underline{Z}$ - water depth usually expressed in meters (the positive direction taken downwards).

INTRODUCTION

The tide line which occurs as a boundary or "front" between two water masses is observed in and near every harbor of the world where river or estuarine water flushes periodically into an ocean as a result of tidal action (Figures 1 and 2). Little of the pertinent physical and biochemical properties is known and published. Even less is known of the effects the phenomenon may have on sound transmission in the sea. This brief study began in late October 1959 and terminated in early December 1959.

At Panama City (Figure 3) in the vicinity of the channel between St. Andrew Bay and the Gulf of Mexico, a distinct tide line may be observed almost daily. It was suspected that this phenomenon might have an adverse effect on the use of underwater acoustic gear in these waters. The investigation which was undertaken is an attempt to increase our fundamental knowledge of tide lines and to increase our understanding of the problems encountered by acoustic gear in harbor approach environments.

The use of the terms "front" and "tide line" which are selected to describe this phenomenon are defined as follows for the purpose of this report. The word "front" as used here is analogous to its use in meteorology where a front describes a boundary surface between two dissimilar air masses. In this case we are describing a boundary surface between two dissimilar water masses. The expression "tide line" was chosen because the origin, movement and surface geometry of this phenomenon appear to be closely linked to tidal forces and in particular, to the tide cycle observed at Panama City.

The "tide line" is manifest at the sea surface and is observed to be a long, continuous, meandering line of foam, detrital matter, and trash. This persistent accumulation of matter at the sea surface in a narrow zone suggests a zone of convergence. The tide line then locates the line of intersection of the sea surface with the "front" or vertical boundary surface between two water masses. The difference in color between Bay and Gulf water at the boundary, and at times, temperature and salinity differences across the boundary, support the "front" analogy.

Information applicable to the tide line problem is scarce, and in particular, information concerning the variation in acoustic and other

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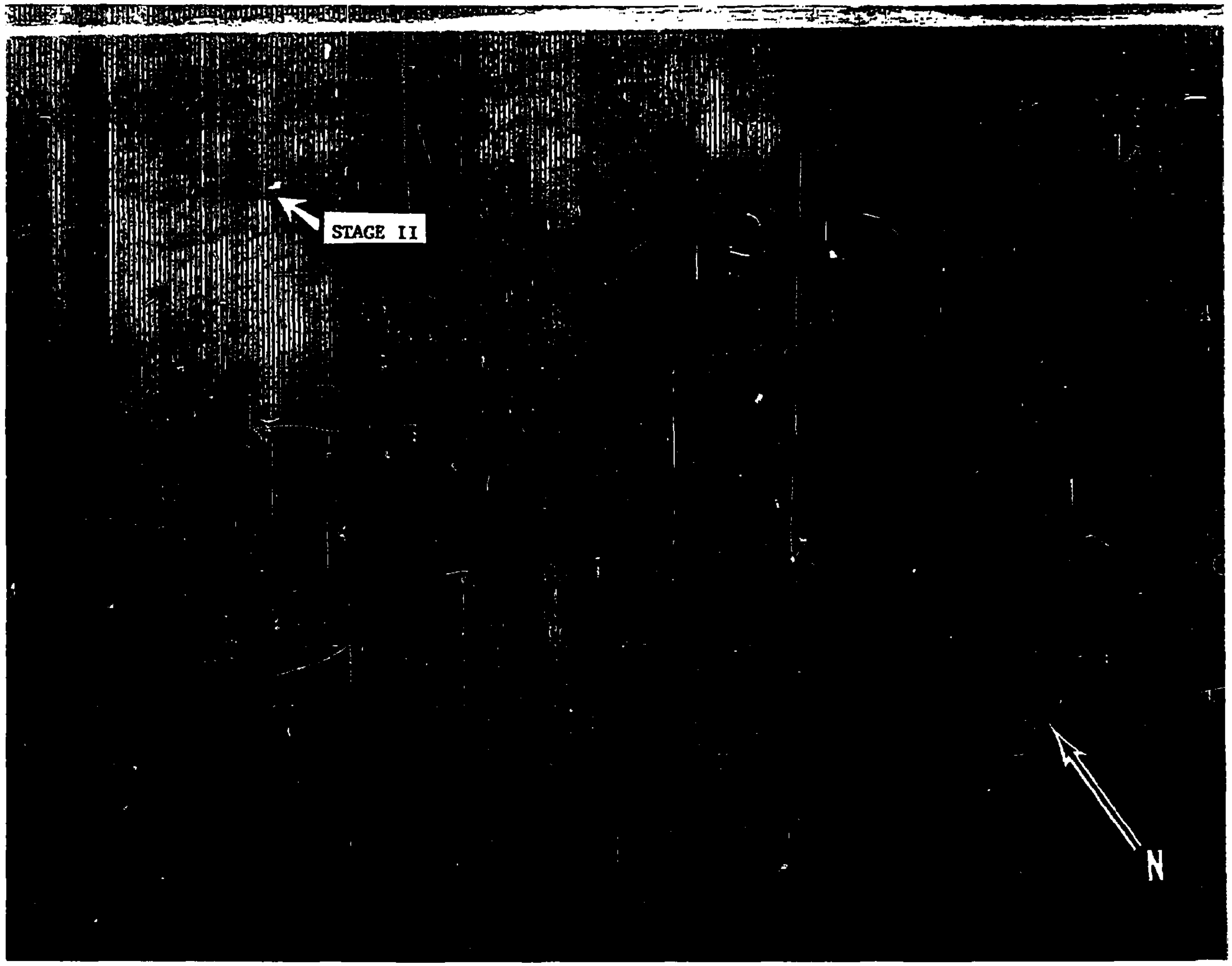

FIGURE 1. AERIAL PHOTOGRAPH OF A TIDE LINE IN MIDSTAGE OF DEVELOPMENT
(Location - Area Southwest of Panama City Jetties Looking North)

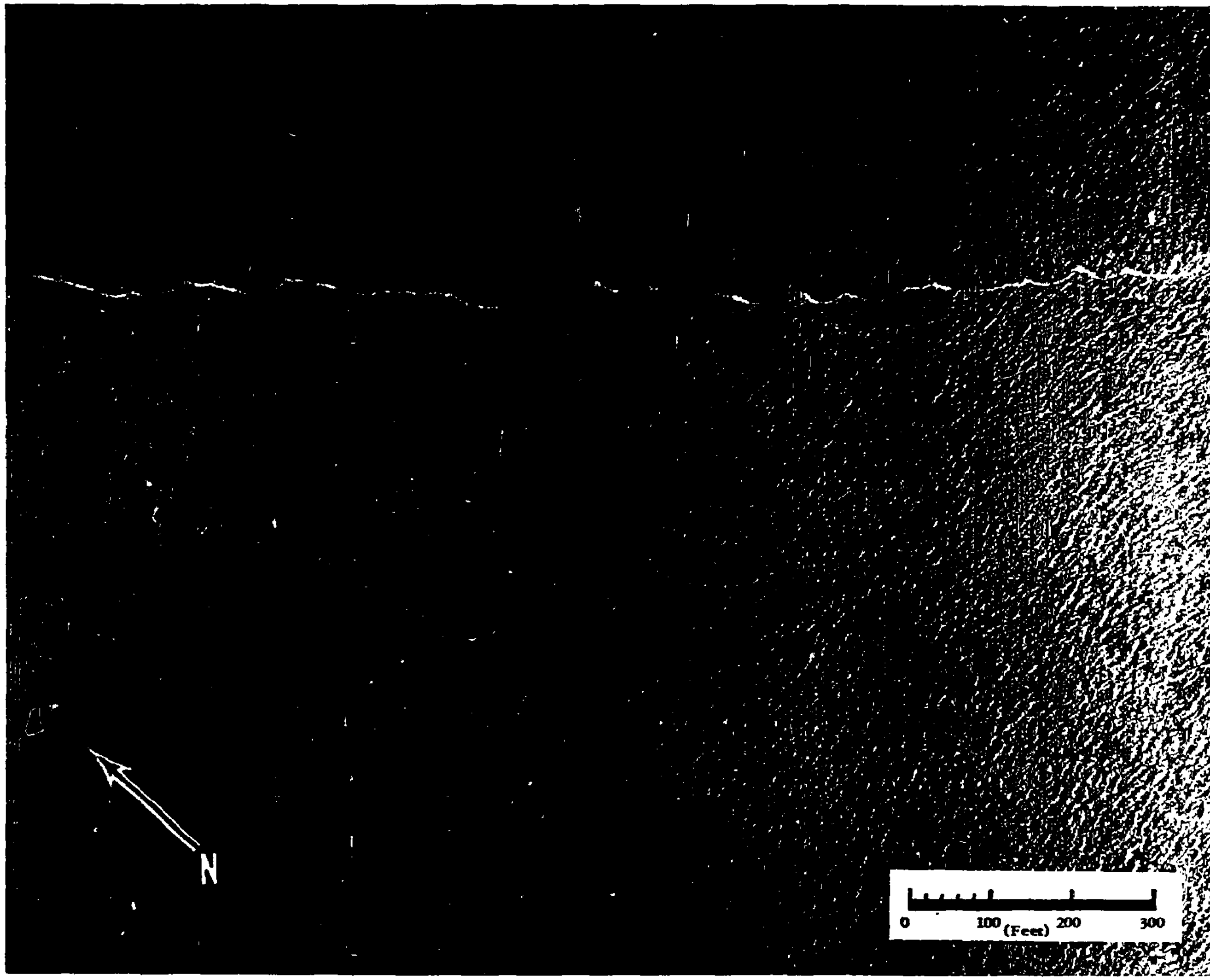

FIGURE 2. AERIAL PHOTOGRAPH OF A TIDE LINE WHICH HAS BEEN MODIFIED BY WAVE ACTION

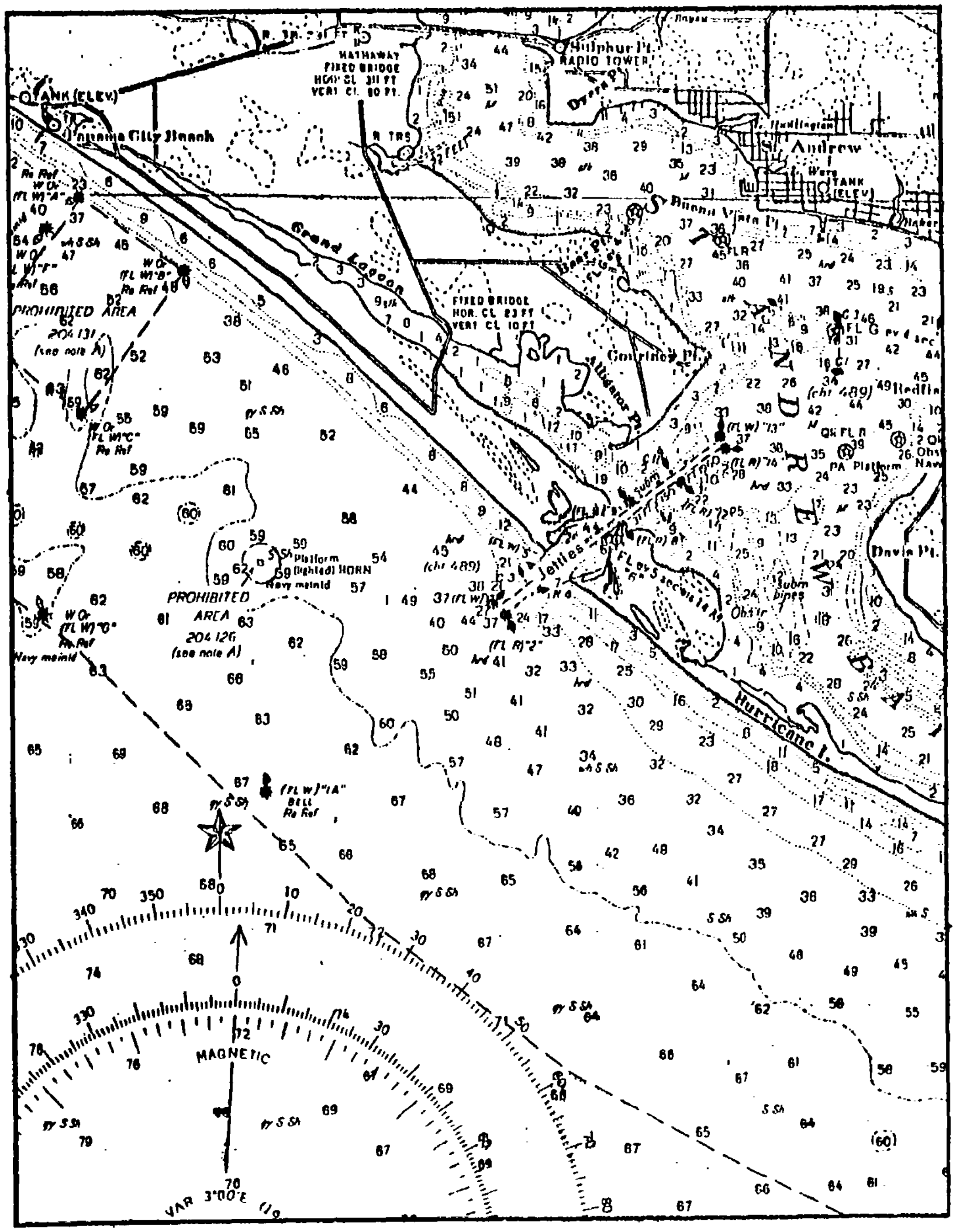

FIGURE 3. CHART OF THE TIDE LINE STUDY AREA

physical properties near tide lines. A search through hydrodynamic theory of classical origin failed also to disclose a suitable or applicable analog or model to the problem described above.

A paper of theoretical interest to this study is that of Bates (1953) on a "Rational Theory of Delta Formation" (Reference 1). His concept of delta formation offers a possible explanation for the phenomenon studied here. Although his study considers the turbulent jet-like sediment flows produced by large rivers entering an ocean, e.g., the Mississippi River, the basic theory is attractive as a first approximation to explain the fan-shaped tide line geometry observed at Panama City.

The concept of a plane jet where mixing is assumed to take place in only two dimensions would appear to fit closely what has been observed in this study (Figure 4). In the plane jet, spreading of the lateral boundaries away from the orifice (e.g., the jetties, Figure 3) decreases downstream so that a parabolic shape develops such that the width of the jet, described by its turbulent boundary, is three times the square root of the distance downstream from the orifice. Although this shape does not fit closely the geometry observed in our tide line there are other interesting features related to the velocity structure which are appealing. The terminal region for such a jet is described to be approximately 2000 times the width of the orifice downstream. At this point the core velocity of the jet is approximately zero ($U_o = 0$).

Although basic jet theory requires purely inertial flow, it is probable that a hydraulic head can exist at river mouths and also at the Panama City jetties during certain stages of the tide. The hydraulic head causes rapid spreading after discharge and higher velocities of the jet. Data which appear in the literature, (References 1 and 8), indicate that such widening is not greater than 3 times the width of the classical plane jet. For example, note the dashed line boundary depicted in Figure 4. Other important factors which must be considered in the shaping of the "tide line fan" is the periodic nature of the flow through the jetties, the prevailing long shore currents which exist and the surface disturbances brought about by wind and swell.

Other aspects of Bates' work are of interest here also; for example, stability criteria for the establishment and maintenance of a plane jet is hypopycnal flow (lower density surface water flowing over higher density Gulf water) through a suitable orifice. Such a condition was observed during the investigation which was conducted.

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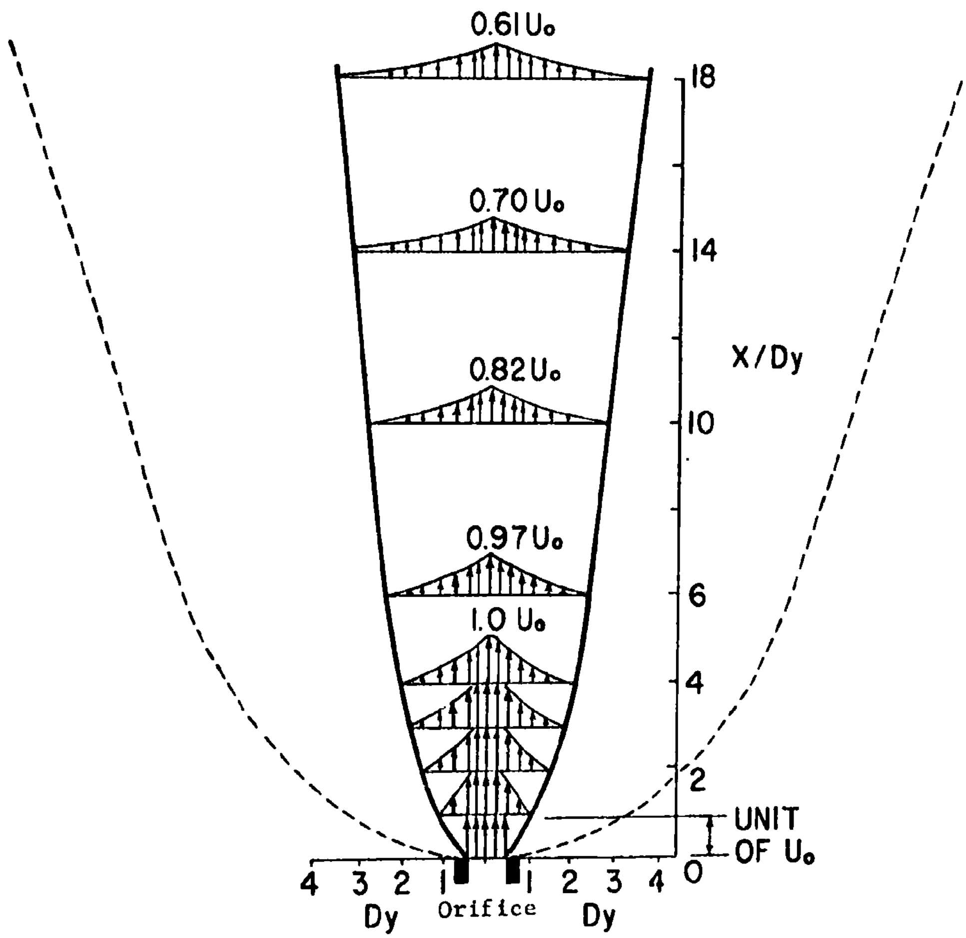

FIGURE 4. DISTRIBUTION OF FORWARD VELOCITY (U) IN A PLANE JET (After Bates 1953)

METHOD OF APPROACH

Concurrent with the literature search a small surface craft, Navy AVRT, was instrumented to collect oceanographic and acoustic data in support of the tide line investigation.

The plan which was followed for this investigation and from which few deviations were made was a daily (weather permitting) preliminary search for the "tide line," an investigation of its surface geometry, and then station observations using available oceanographic and acoustic instrumentation. Stations were taken behind the "front," preceding the "front," and in the discontinuity zone of the front itself at several positions along the perimeter of the tide line. SCUBA-equipped swimmers were used extensively to obtain firsthand descriptions of the interface or boundary which separated the two water masses. Of particular interest to the investigation were descriptions of changes in water color, concentrations of detrital or living matter, evidence of turbulence or mixing between the two water masses at their interface, and the water velocity distribution at this boundary. A number of vertical profiles were taken also to determine the slope of the "front" in the water column.

A secondary task of the tide line investigation was a brief study of the ambient noise level characteristics of tide lines as compared to the ambient noise level of adjacent open Gulf and/or Bay water. A small boat was used for the study because of its desirable self-noise characteristics. Measurements were taken with a battery-operated AN/PQM-1A, a noise measuring set. Measurements were taken within the tide line environment to determine distributions and gradients of temperature, salinity, density and sound velocity. Measurements of water movement, surface wind velocity and estimates of sea state were obtained also. In at least one instance, aerial photographs were taken of the tide line phenomenon using a Laboratory HSL-1 helicopter, as shown in Figures 1 and 2. Fluorescein dye was used by divers to study vertical and horizontal velocity distributions associated with the interface of the two water masses. Underwater still and motion picture cameras were utilized to record dye marker changes in space and time. Horizontal visibility measurements were taken also by divers using the Secchi disc. A more detailed discussion of the instrumentation which was used is presented in Appendix A.

RESULTS OF THE INVESTIGATION

Bay water was observed to flow in a thin (2- to 4-feet thick) sheet overlying more dense Gulf water during the period of this investigation. Even though in a few instances extreme velocity gradients were observed

by divers, little vertical mixing appeared to be taking place across the front or boundary. The two-layer system was apparently stable, adding credence to the idea that this phenomenon is probably the result of a modified plane jet flow.

The period covered by the field study of "tide lines" included all of November and a week in December. This season is characterized by a change in climate during which cold northerly air masses tend to cool warm Gulf water at a rapid rate from the sea surface down to a depth of the thermocline, which is dependent on the wind velocity. Such cooling tends to create an unstable thermal condition in the water column which can result in over-turning and additional mixing if the temperature gradient is large enough, and provided there is no mechanism by which a dynamic stability due to convection cells is found to exist.

Such inversions were observed a number of times during the latter half of November and in early December. The temperature gradients were for the most part, slight, and the water column remained stable as a result of salinity distributions (Appendix B). Extreme gradients in both temperature and salinity were noted only in St. Andrew Bay. Again, however, the water column was stable because of the vertical distribution of salinity.

There were a number of days during the survey period when tide lines were not observed. Important criteria appeared to stem from a number of causes individually and/or collectively contributing to the disintegration of the tide line and a two-layer system. The stage of the tide, the wind velocity, the sea state, and the density structure of the water column were important to the formation or lack of formation of a tide line. High tides, wind velocities in excess of 14 knots, and sea states greater than number 2 would destroy or remove an existing tide line. Following a squall or storm in the Gulf, one to two days were required to re-establish a two-layer system from which a "line" could be distinguished.

Figures 5 through 7 display several tide line configurations which were observed during the survey period. The figures represent different stages of "frontal" development as a consequence of tide, current and wind. Without exception, the measurements taken to establish cross-sections of the water mass through the "front" and the overlying Bay water demonstrated that the near surface Bay waters occurred as a thin sheet 2 to 4 feet thick as shown in Figure 8.

Thickening of the surface water to produce a slope between the two water masses was not evident in the Gulf but did occur in St. Andrew Bay as one proceeded up the ship channel. Depths to which the interface extended were 12 to 15 feet in the vicinity of Dyers Point, as shown in Figure 8. The stage of the tide appeared to have little effect on the depth of the interface in the lower reaches of St. Andrew Bay, e.g., from Dyers Point to the jetties.

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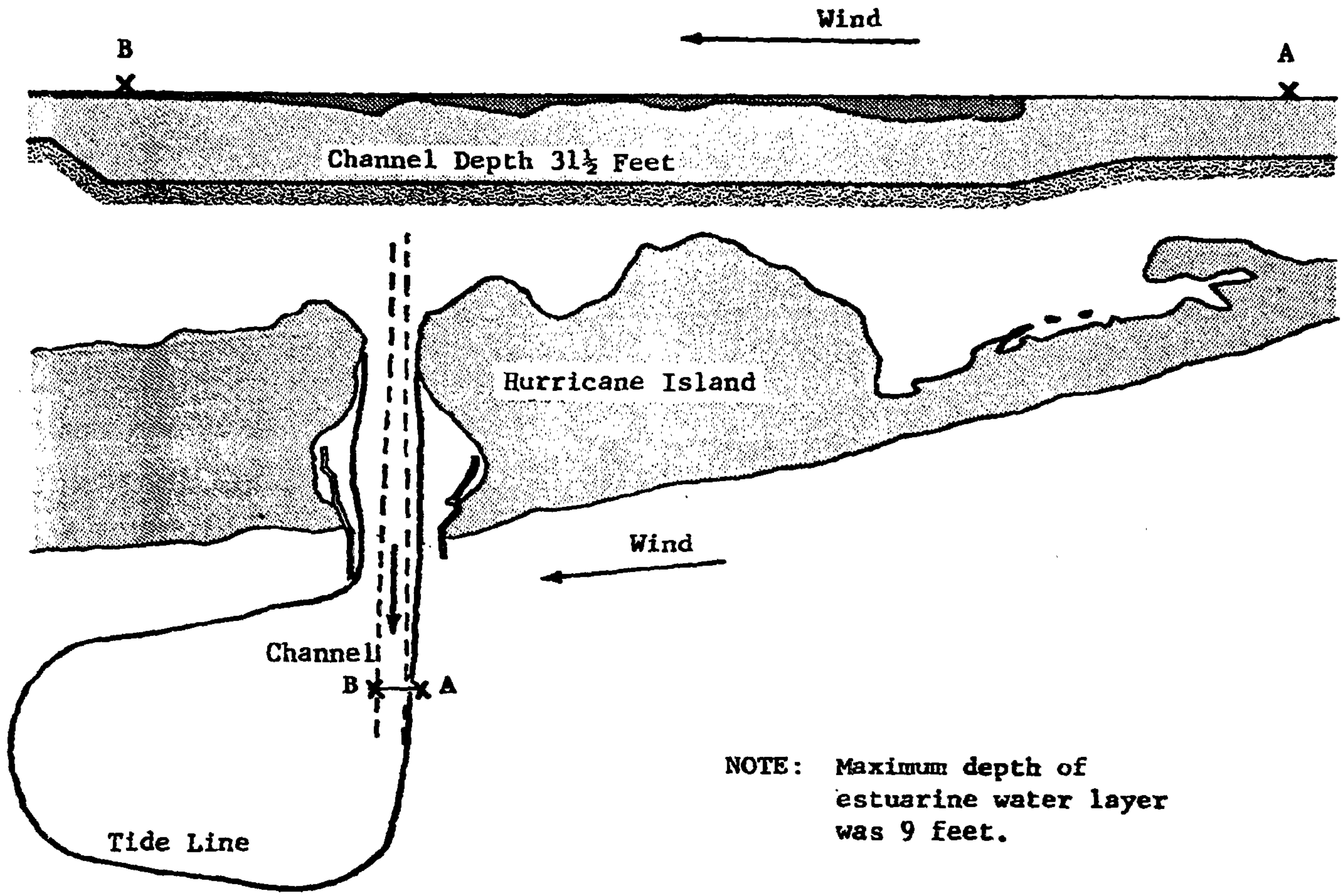


FIGURE 5. PLAN AND PROFILE VIEWS OF THE TIDE LINE OF 20 NOVEMBER 1959

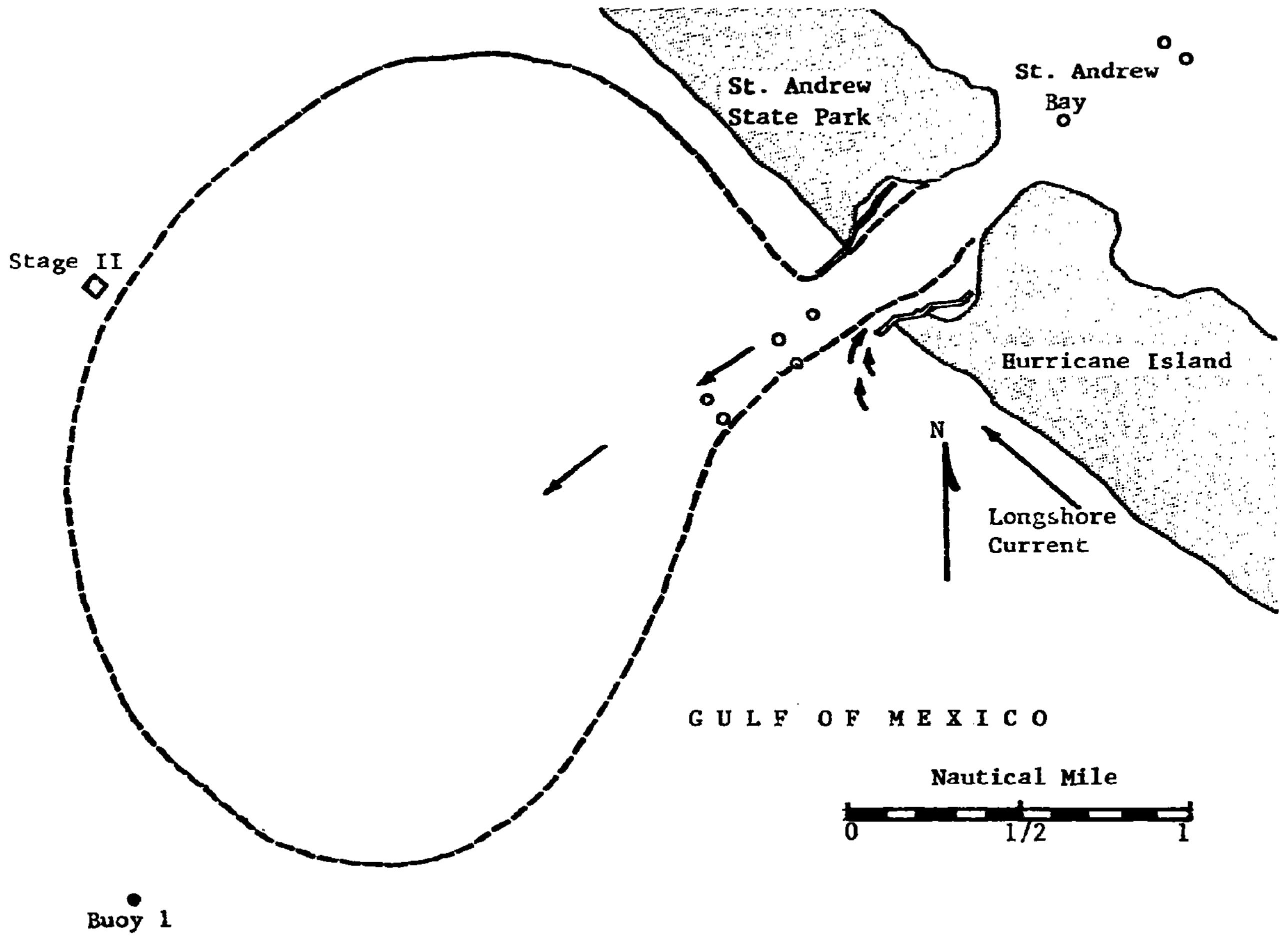


FIGURE 6. THE TYPICAL EARLY WINTER TIDE LINE

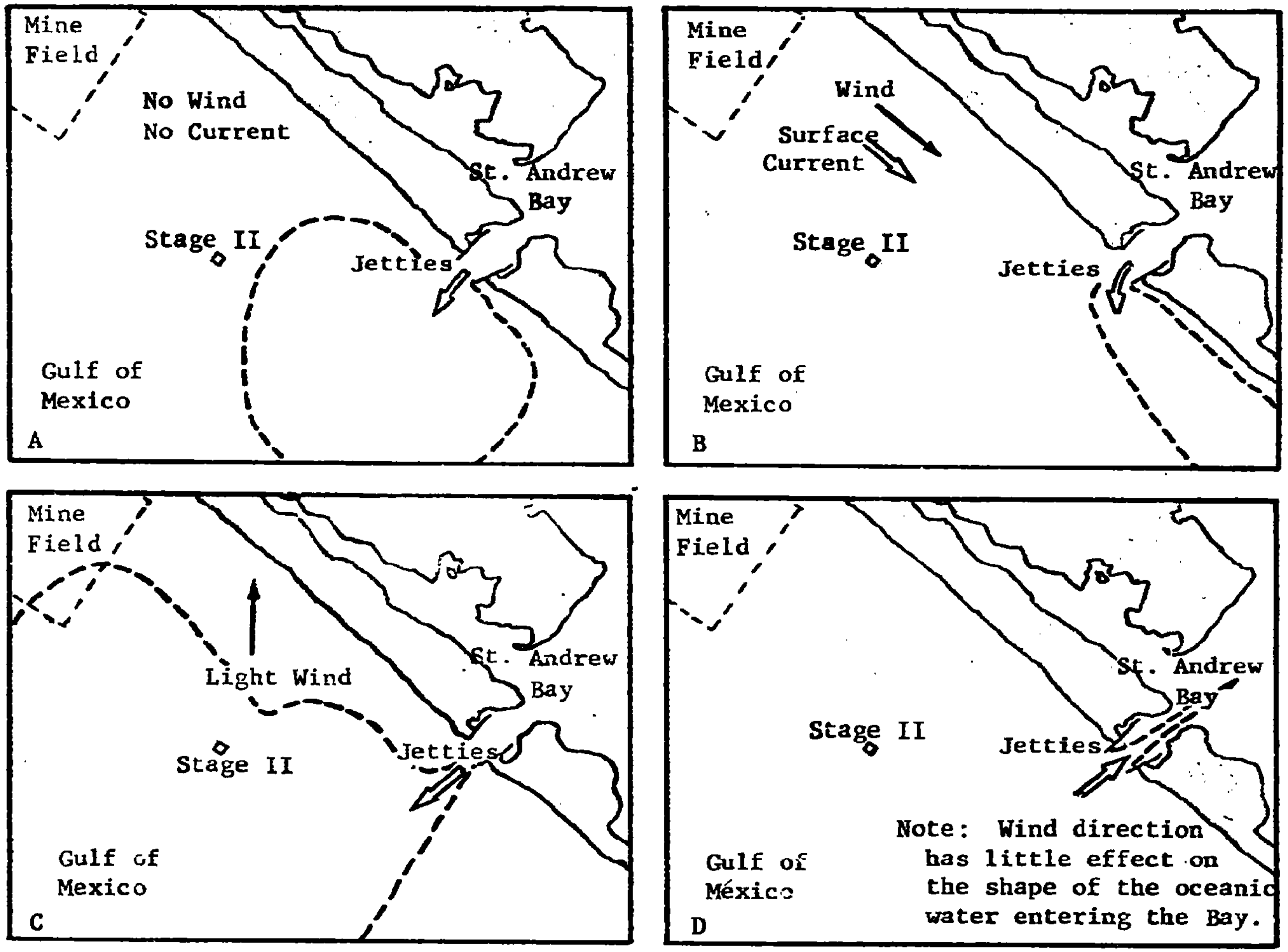
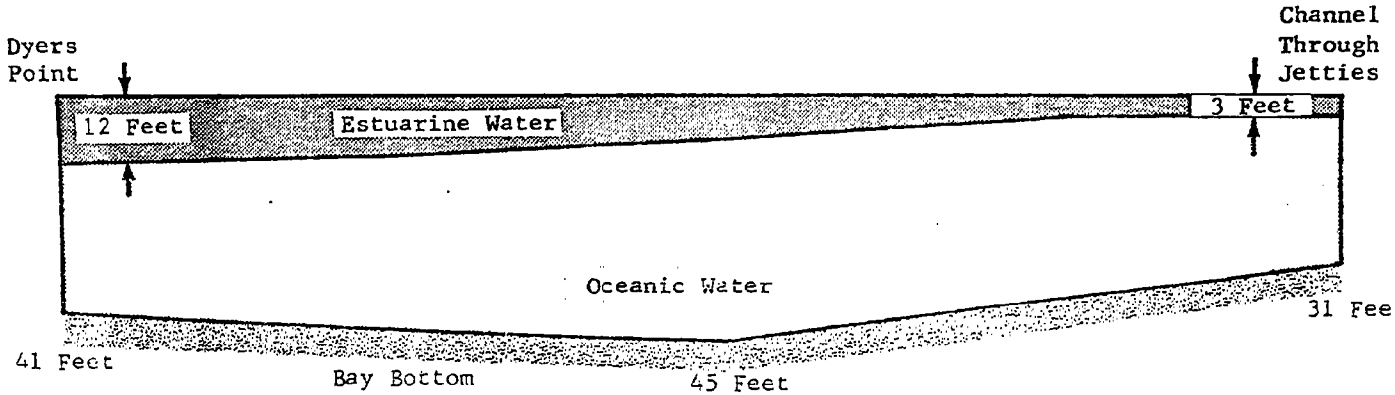
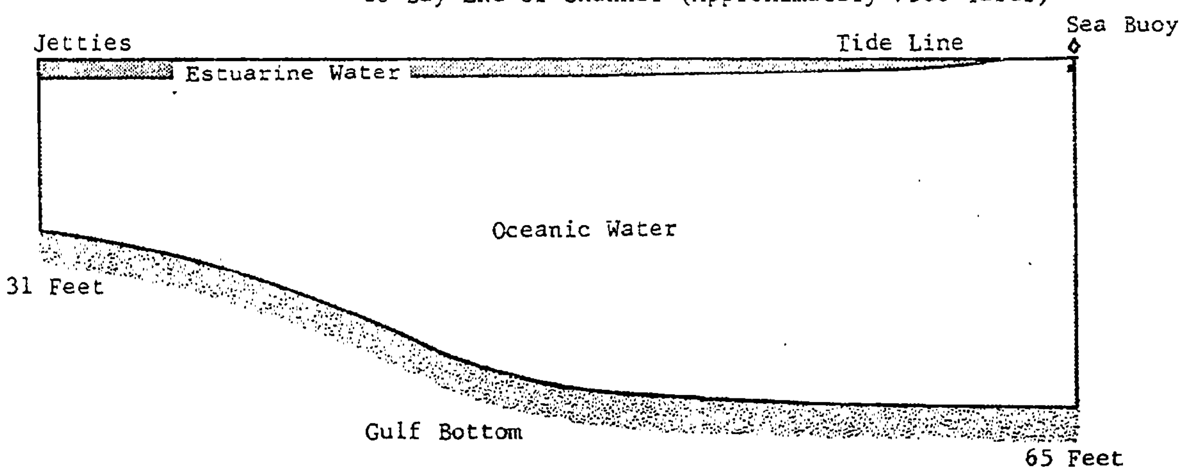


FIGURE 7. DIFFERENT CONFIGURATIONS OF THE TIDE LINE OBSERVED AT PANAMA CITY



A. St. Andrew Bay Profile From Dyers Point to Bay End of Channel (Approximately 7500 Yards)



B. Gulf of Mexico Profile From Jetties to Point Near Sea Buoy (Approximately 5500 Yards)

FIGURE 8. PROFILES OF THE TWO LAYER TIDE LINE SYSTEM FOR ST. ANDREW BAY AND THE GULF OF MEXICO

Both temperature and salinity gradients were observed to occur at the boundary as defined by sound velocity gradient measurements. Because of the ease in operation and the print-out characteristics of the sound velocity meter recorder, this instrument became the prime tool for locating an interface in the water column. The depth of the interface as indicated by a sudden change in meter reading when lowered in discrete steps was in every case confirmed by SCUBA divers. Bathythermograph traces and the tele-thermometer monitor also were useful in cross-checking gradient depths indicated by the sound velocity meter.

Because of possible sound propagation effects applicable to SONAR behavior, measurements were taken to determine sound velocities in the different layers of the water column by two methods. One method described above was the use of a sound velocity meter, and the other independent method required computation of the sound velocity from the measured temperature and salinity distributions. Figure 9 presents temperature and sound velocity versus depth measurements.

Appendix B presents the data of 25 typical station samples selected for this report. Sound velocity differences within the upper 15 feet of the water column vary from 2 ft/sec to 34 ft/sec in the open Gulf and from 3 ft/sec at the jetties to 56 ft/sec in St. Andrew Bay. The major portion of the differences measured usually occurred over a very short vertical distance, e.g., one to two feet. Sound velocity gradients as high as 5 ft/sec/ft were not uncommon in the region of the interface. It has been established by Carsola, Herzfeld, et al (References 2 and 4) that sound velocity gradients of this order of magnitude are sufficient to cause extensive refraction of the transmitted and/or received sound energy at such a boundary.

The results of an ambient noise level study which was undertaken as a secondary task of this investigation are presented in Figure 10. Measurements of ambient noise level were made near the tide line as well as in nearby open Gulf and Bay areas in order to compare results. Discrete bands of frequency between 100 and 10,000 cycles per second were selected and measured with the Navy's PQM-1A noise measuring set, in db (reference one dyne/cm^2). Although the results of this study were somewhat inconclusive, it is felt that tide lines at certain times of the year may exhibit increased ambient noise levels as compared to the adjacent open water background noise levels, due to biological activity which is often observed in these "fronts."

Measurements of current velocity differences vertically as well as horizontally through the water column were attempted using fluorescent dye marker capsules, motion picture photography and SCUBA-equipped divers. The usual vertical distributions of velocity observed were of two basic configurations. A two-layer flow system and a one-layer flow system were usually observed depending on tidal phase and surface wind at the time of

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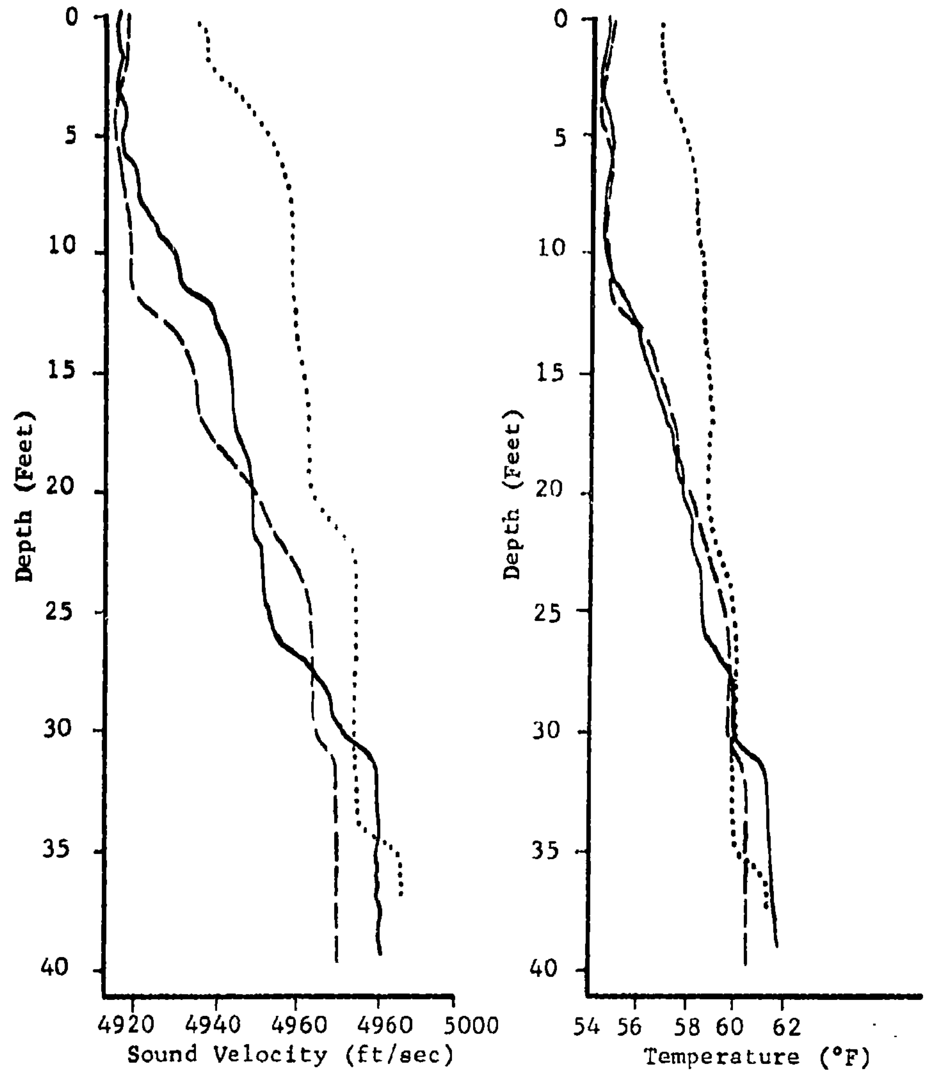

FIGURE 9. TYPICAL CURVES OF MEASURED SOUND VELOCITY AND TEMPERATURE VERSUS DEPTH

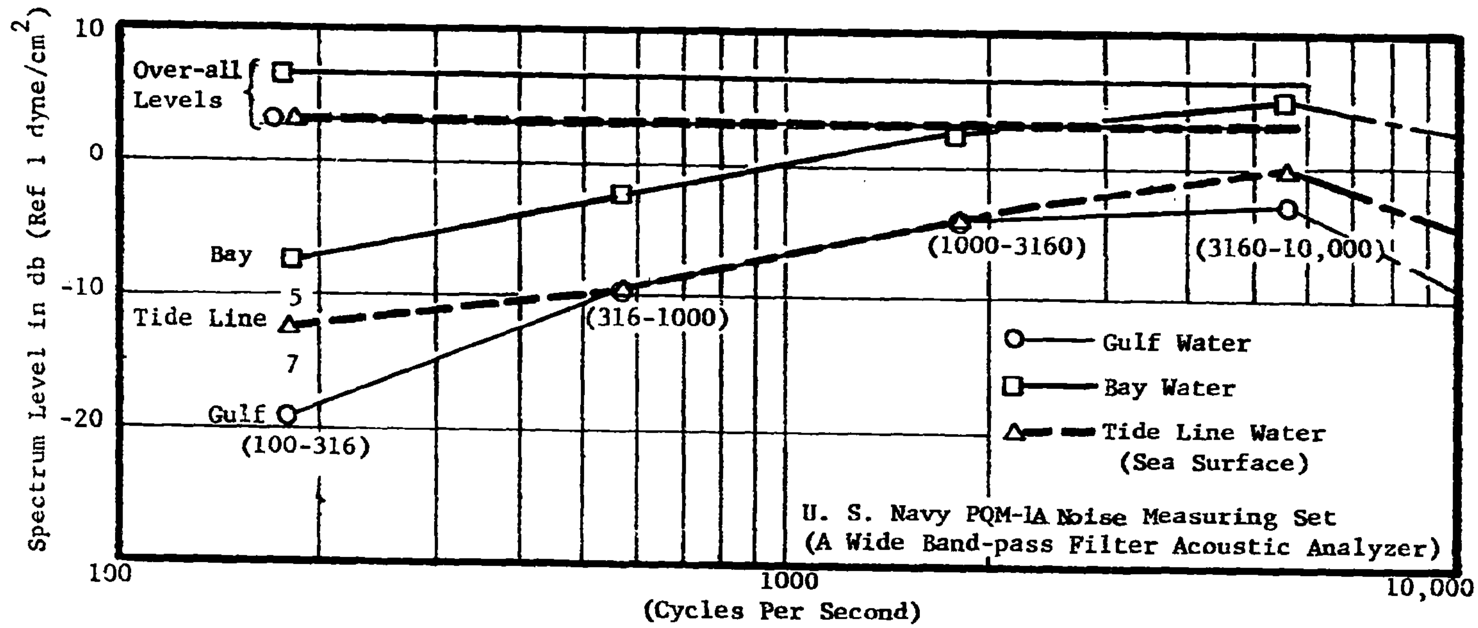

FIGURE 10. AVERAGES OF AMBIENT NOISE LEVEL (Tide Line Investigation)

observation. Velocities usually decreased with depth to become negligible near the sea floor. On calm days during equatorial tides at times of slack tide, little or no water motion was observed but the tide line boundary and interface could be determined. A marked vertical shear of horizontal motion is a characteristic of "tide line" flow.

A photographic record of this flow was obtained only once; photographs of dye streaks were taken through the water column and a plot of the data fits best what appeared to be a three-layer system, as shown in Figure 11. A zone of intense velocity gradient and shear occurred in the region of the tide line interface approximately 3 feet beneath the sea surface and the second zone of velocity shear occurred a few feet above the ocean floor. Other instances of velocity shear zones at the tide line interface were observed and reported by the divers but no other photographs were obtained.

The "front" or boundary which was manifest at the sea surface as a line of foam, slick and detrital material was observed to progress at speeds up to 1/4 knot under the influence of moderate winds in the Gulf. The "tide line" which was observed to extend considerable distances in the NAVMINDEFLAB mine fields (Figure 3) and several miles out to sea was altered in its shape by waves, (e.g., swell), as well as by prevailing currents and circulation patterns. Figures 1 and 2 illustrate the effect of swell approaching a "tide line" from an angle producing a continuous array of foam cusps. Even so the front remained intact and was not broken up during the period of observation.

During sea state conditions exceeding a number 2 and/or under wind conditions in excess of 14 knots, the tide line was difficult to locate either at the sea surface or in the water column with the instrumentation that was available for this investigation.

Visibility measurements which were taken by swimmers at different levels and within each water mass are presented in Table 1. During most of the survey period, clear, isothermal and isohaline conditions typified the Gulf water mass, in contrast was the less dense more turbid and discolored St. Andrew Bay water. An exception to the conditions described above would occur when squall or storm conditions thoroughly mixed Gulf and Bay water stirring up bottom sediments to discolor and obscure the entire water column.

Differences in visibility between Gulf water and Bay water varied from 0 to 60 per cent as shown in Table 1. It is not known whether visibility differences were due to differences in absorption of light because of color differences, or because of the difference in the number of light scatterers in the two water masses or because of a combination of these effects. No samples were collected of the particulate concentrations which were present. In a recent study of the concentration and size distribution of particulate matter in sea water conducted at

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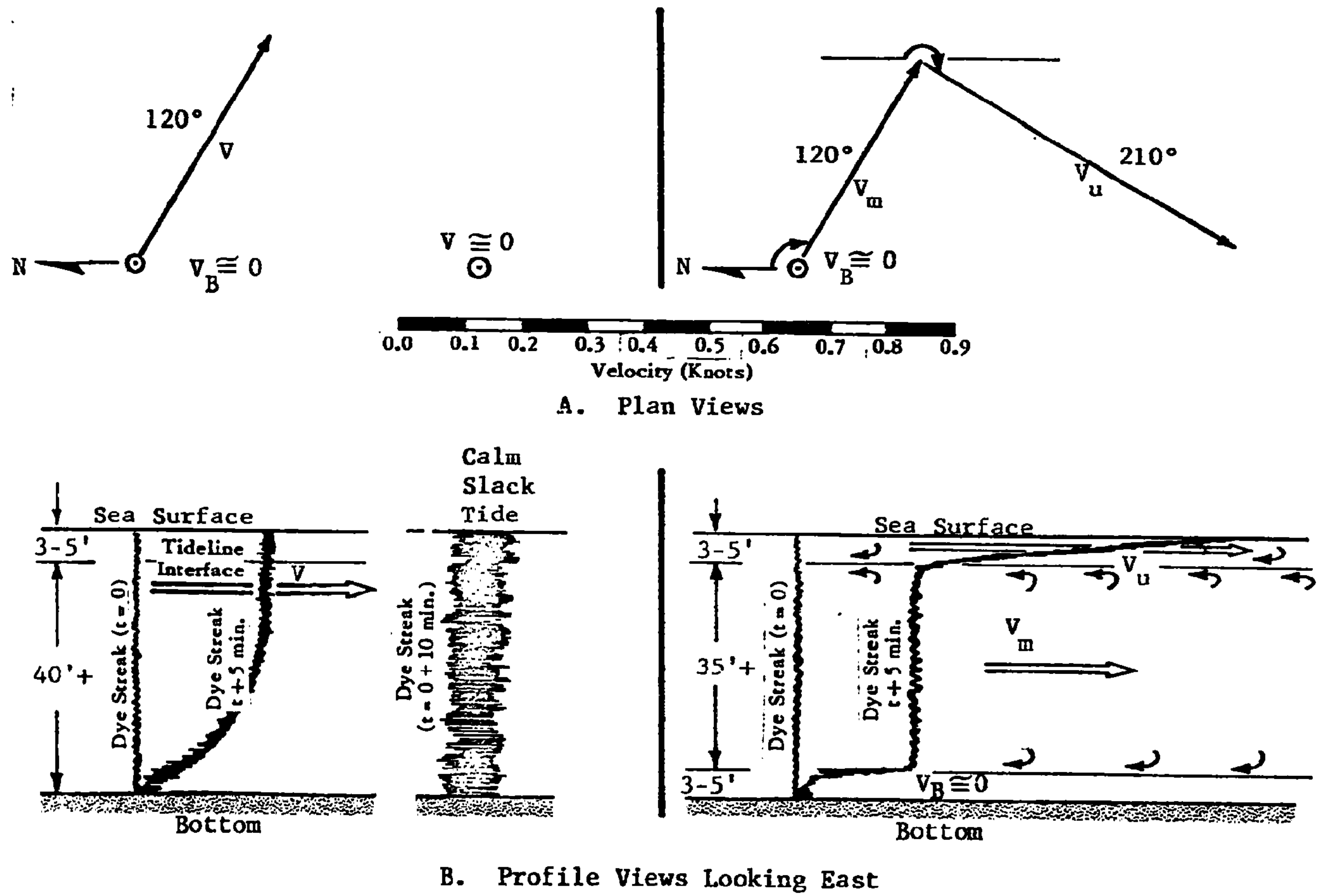

FIGURE 11. THE DISPLACEMENT OF VERTICAL DYE STREAKS THROUGH A TIDE LINE INTERFACE (FROM DIVER OBSERVATIONS)

TABLE 1

HORIZONTAL SECCHI DISC MEASUREMENTS
THROUGH THE TIDE LINE WATER COLUMN
(Visible Range in Feet)

Date	Type of Water	White	Black
4 Nov	Gulf	19	11
	Bay	14	5
	% Difference	(26)	(54)
9 Nov	Gulf	45	35
	Bay	32	20
	% Difference	(29)	(42)
10 Nov	Gulf	52	40
	Bay	20	15
	% Difference	(61)	(62)
13 Nov	Gulf	22	17
	Bay	22	16
	% Difference	(0)	(6)
23 Nov	Gulf	25	21
	Bay	11	9
	% Difference	(56)	(57)
4 Dec	Gulf	34	29
	Bay	24	19
	% Difference	(30)	(34)
8 Dec	Gulf	10	9
	Bay	7	7
	% Difference	(30)	(22)

NAVMINDEFLAB, Tolbert found that at all depths the number of particulates in St. Andrew Bay water in the summer exceeded the number found near shore in Gulf water by a factor of 2 or more (Reference 7).

SUMMARY AND CONCLUSIONS

The existence of a tide line at the sea surface in the region of an approach to a harbor signifies the presence of at least two water types, one overlying the other. The boundary between the two fluids locates the surface of greatest sound velocity gradient in the water column, e.g., as much as 14 ft/sec/ft (Appendix B).

The type of inflow observed at Panama City, for the survey period was hypopycnal (surface water less dense than underlying bottom water). In contrast to hypopycnal inflow is hyperpycnal inflow or a turbidity current flowing from a river or estuary into a less dense ocean. This latter case has not been observed at Panama City. A third case intermediate to the two described above is homopycnal inflow in which the inflow water mass has the same density as the oceanic water. This case was not observed at Panama City during the investigation but it is believed that approximate homopycnal inflows can occur here.

The surface geometry of the tide line boundary which was observed during this investigation suggests a modified plane jet pattern of circulation such as was described by Bates for the Mississippi River inflow into the Gulf. Stability effects of hypopycnal inflow which were observed for the Panama City case, with overlying less dense Bay water configured in a thin sheet, supports the plane jet hypothesis offered here in explanation of the tide line phenomenon.

During a rising tide the "tide lines" in the Gulf become discontinuous, are dispersed and gradually disappear. "Tide lines" which develop in St. Andrew Bay during an incoming tide may be very distinct in the lower part of the Bay (e.g., near the jetties), but at late stages of the rising tide and in the upper reaches of the Bay the lines are discontinuous, may run together and display few clear patterns of behavior. Sound velocity and temperature measurements taken in the water column as one progressed up the Bay defined a slope boundary between two water masses shallow (3 to 4 feet) at the jetties and sloping gradually to depths of 15 feet near Dyers Point, as shown in Figure 6. It is believed that owing to the complex geometry and topography of St. Andrew Bay, coupled with a complex circulation pattern produced by the many sources of run-off water, e.g., Grand Lagoon, The East Pass, East Bay and North Bay, that several separate and distinct "tide lines" are able to form, mingle and interfere with each other within the Bay. The

interface depth between oceanic bottom water and the less dense overlying Bay water, whatever the source, would remain essentially the same. The slope of the interface is a result of the "salt wedge" phenomenon which occurs in rivers and estuaries. This phenomenon has been reported extensively in the literature, e.g., Farmer, Morgen, et al, (Reference 3.)

The sea surface "tide line" which was easily identified as a line of foam, slicks, and detrital material was observed to progress at speeds up to 1/4 knot under the influence of moderate winds in the Gulf. The "line" or "front" frequently extended into the NAVMINDEFLAB test areas and to sea, e.g., distances of 3 to 4 miles from the jetties.

The differences of ambient noise level between St. Andrew Bay and nearby open Gulf were significant over the frequency spectrum considered, e.g., 100 to 10,000 cycles per second, Reference, 1 dyne/cm^2 (Figure 10). The estuarine water exhibited higher noise levels by approximately 7 db at all frequencies measured than did the Gulf water, possibly due to the higher incidence of small animals (e.g., plankton) observed in local bay waters at this time of the year (Reference 7).

Maximum temperature and salinity gradients are observed to occur at the same boundary as marked by the sound velocity measurements. Temperature gradients were usually quite small but in general displayed a thermal inversion, e.g., cold bay water overlying warmer Gulf water. Salinity gradients tend to offset the unstable thermal structure resulting in a stable water column.

During sea state conditions in excess of a number 2 and/or under wind conditions in excess of 14 knots, the "tide line" is difficult to locate either at the surface as a line or within the water column as an interface or "front."

It is concluded that "tide lines" and the associated two-layer mechanisms can have an adverse effect on underwater acoustic equipment. One mechanism which was established, based on sound velocity measurements taken under this investigation and on results reported by Carsola and Herzfeld (References 2 and 4) is extensive refraction by sound velocity gradients. Sound velocity gradients at Panama City are not as large as those typical of the Atlantic and Pacific Ocean near shore environments, and the fact that a significant gradient occurs for a clean harbor environment as is found at Panama City, Florida, only emphasizes the importance of the effect described here.

RECOMMENDATIONS

On the basis of the results of the preliminary investigation described above, it is recommended that applied studies of the tide line phenomenon be continued. In particular:

1. Obtain instrumentation suitable for conducting sound attenuation measurements in the environment, e.g., a sound attenuation meter and/or a small boat SONAR.

2. Conduct brief field investigations during each season of the year in order to establish "tide line" changes which are believed to be brought about by seasonal changes in the distribution of variables in the water column, e.g., a change from hypopycnal inflow to homopycnal inflow during periods of low fresh water dilution, e.g., a "quick-dunk" sampling of the tide line water column would suffice to establish changes or trends.

3. Continue a routine field investigation of the profile geometry of the boundary or interface for detail; in particular, look for seasonal depth changes of the tide line interface which adversely affect mine hunting SONARS.

4. Investigate "tide line" phenomenon in other harbors in order to compare different harbor approach "tide line" environments in terms of expected SONAR performance difficulties.

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APPENDIX A

INSTRUMENTATION

OCEANOGRAPHIC AND ACOUSTIC INSTRUMENTATION

Instrumentation which was used for the tide line investigation consisted of oceanographic and acoustic equipment which was available at the Laboratory at the time the field investigation began, November 1959.

The vertical distribution and gradient of temperature were measured with a shallow-water bathythermograph used in conjunction with a glass-mercury thermometer mounted in a water-sampling bucket. Temperature and depth accuracy of the system is respectively ± 3° F. and ± 0.5 feet. The relative temperature accuracy of the bathythermograph or its response sensitivity is considered to be ± 0.1° F.

A second temperature measuring instrument which was used as a check to support bathythermograph measurements was a tele-thermometer which consisted of a string of 12 thermistor beads spaced at 2-foot intervals. The instrument was non-recording and had a slow response time (30 sec), but served as an excellent monitor of the vertical temperature structure when "on station."

The vertical distribution and gradient of salinity were obtained with a Kemmerer water sampler. Samples are collected one at a time in sequence usually from bottom to surface at selected depths. Depths were determined from the measured marks on a line to which the water sampler was attached. For the purposes of this study three to five water samples were collected at each station, the number depending upon the water depth. Salinities were determined by a chemical titration technique first described by Knudsen (Reference 5). The accuracy of salinity determination by this method is approximately ± 0.02 o/oo.

Water densities and/or σ_t were computed from temperature-salinity nomograms and may be considered reliable to ± 0.0005 gm/cm^3 for relative differences in specific gravity. Sound velocities were computed from temperature and salinity measurements using Kuwahara's tables and nomogram, and may be considered accurate to ± 3 ft/sec (Reference 6). Sound velocity measurements were taken also with a National Bureau of Standards sing-a-round sound velocity meter. Relative differences in sound velocity are assumed to be reliable to ± 1 ft/sec. The absolute accuracy of this instrument is questionable, however; differences between computed and measured sound velocity were as much as 50 ft/sec (Appendix B). The depth of each sound velocity observation was

determined by a metering wheel through which the line supporting the sound velocity meter was attached. Accuracies of depth with this device are good to ± 0.5 feet for water depths less than 100 feet.

Several attempts were made to use a sound attenuation system to measure attenuation characteristics of the two water masses as well as attenuation through their interface. Components which were vital to the electronic stability of this system were not available during the survey period, therefore no reliable attenuation data were obtained.

A standard USN AN/PQM-1A Noise Level set was used to measure ambient noise levels in the vicinity of and adjacent to tide lines. The frequency range covered by this instrument is 100 to 10,000 cycles per second in discrete bands.

Vertical and horizontal visibility measurements were made by divers using two standard black and white Secchi discs. The measurements obtained by this method gave approximate comparisons of turbidity conditions which were found between the two water masses. The distance at which a 30-cm diameter Secchi disc will disappear from view is a measure of the visible range in the water layer or column measured. Despite the number of independent variables involved in this simple technique, some of which are subjective, reproducible results are obtainable.

An attempt was made to use a Chesapeake Bay Institute tri-filter hydrophotometer to measure differences of water visibility, (i.e., per cent transmission of light) but the sea-unit flooded, damaging the instrument, and parts were not available for its repair.

A few current velocity measurements were obtained with an Ekman type mechanical current meter. This instrument, when calibrated, has an accuracy in speed and direction of ± 0.1 knot and ± 5° magnetic. Of greater interest to the study than the measure of absolute current velocity was the measurement of velocity gradients and the identification of velocity shear zones. Fluorescein dye was streamed vertically and horizontally through the water column to present a visible uniform streak that could be photographed and later studied.

Wind velocities were measured using a portable anemometer. Accuracies obtainable with this instrument are estimated to be ± 2 knots of wind speed and ± 10 degrees of direction.

Sea state conditions were not measured directly, but were estimated by the personnel participating in the field measurements.

APPENDIX B

TABLES

TABLE B1. A COMPARISON OF TIDE LINE SOUND VELOCITY MEASUREMENTS BY TWO DIFFERENT TECHNIQUES IN ST. ANDREW BAY

					Sound Velocity		
Date - 1959	Depth (feet)	Temperature (F)	Salinity o/oo	gms/cm^3	I Computed ft/sec	II Measured ft/sec	I - II Difference ft/sec
1 Dec	5	59.8	30.19	22.18	4920	4967	-47
	10	60.5	31.15	22.85	4926	4975	-49
	15	60.9	31.89	23.40	4933	4982	-49
4 Dec	0	54.6	26.69	20.10	4875	4915	-40
	30	60.0	30.88	22.70	4924	4971	-47
	0	54.9	26.96	20.27	4878	4919	-41
	30	59.6	32.12	23.70	4926	4973	-47
	0	56.8	28.49	21.24	4897	4936	-39
	35	60.0	32.83	24.20	4931	4985	-44
	0	57.0	27.61	22.06	4893	4931	-38
	32	60.0	32.88	24.24	4931	4985	-44
	0	61.8	33.49	24.49	4944	4988	-44
	40	62.1	33.66	24.57	4946	4991	-45

TABLE B2. A COMPARISON OF TIDE LINE SOUND VELOCITY MEASUREMENTS BY TWO DIFFERENT TECHNIQUES IN THE GULF OF MEXICO

Date - 1959	Depth (feet)	Temperature (F°)	Salinity o/oo	gms/cm^3	Sound Velocity I Computed ft/sec	Sound Velocity II Measured ft/sec	Sound Velocity I - II Difference ft/sec
5 Nov	0	75.1	32.57	21.82	5008	4990	18
	8	75.1	32.72	21.94	5009	5000	9
	15	75.2	32.95	22.11	5010	5000	10
5 Nov	0	75.1	32.92	22.09	5009	4998	11
	8	75.1	32.88	22.06	5009	5000	9
	15	75.2	32.97	22.12	5010	5000	10
9 Nov	0	67.7	30.30	21.03	4965	5007	-42
	5	68.7	30.28	21.09	4969	5012	-43
	15	71.6	33.71	23.26	4995	5041	-46
23 Nov	0	66.0	32.97	23.53	4965	4995	-30
	8	66.0	33.06	23.60	4965	5006	-41
	15	66.0	33.03	23.58	4965	5011	-46

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The concentration of foam and trash to form a visible line along the boundary between two dissimilar water masses is a daily occurrence in the waters near Panama City, Florida. The name 'tide line' is used to designate this phenomenon as its development and degeneration coincide with the ebb and flow of the tide. During the falling tide the water from St. Andrew Bay flows through the jetties into the Gulf of Mexico, spreading outward as a thin surface layer. A brief investigation of this estuarine sea water boundary, carried out under various weather and sea conditions, was undertaken in the early

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3. Tidewater--Boundary layer

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